

Dr. Fahrn



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PRACTICAL TESTS WITH THE "AUTO CONTROL SLOT"

By G. Lachmann

PART II: DISCUSSION

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PRACTICAL TESTS WITH THE "AUTO CONTROL SLOT"*

By G. Lachmann

PART II: Discussion

Dr. W. Pleines.-- For some time the D.V.L. (Deutsche Versuchsanstalt für Luftfahrt) (German Aeronautic Institute) has been investigating the question of the applicability of Handley Page slotted wings to German airplanes. Comparative gliding tests were made with open and closed slots on an Albatros L 75 airplane equipped with the Handley Page "auto control slot." This investigation served to determine the effect of the auto control slot on the properties and performances of airplanes at large angles of attack. The most important problems were as to whether the angle of glide at small angles of attack can be increased by the adoption of the auto control slot and, in particular, as to whether the flight characteristics at large angles of attack are improved

*"Praktische Erfahrungen mit dem automatischen Spaltflügel," a paper read before the Wissenschaftlichen Gesellschaft für Luftfahrt, March 17, 1930. From Zeitschrift für Flugtechnik und Motorluftschiffahrt, September 15, 1930, pp. 440-448. For Part I (Dr. Lachmann's lecture) see N.A.C.A. Technical Memorandum No. 593.

thereby and equilibrium in gliding flight is guaranteed even at larger than ordinary angles of attack.

The arrangement and form of the auto control slot, whose functioning has just been described in detail by Lachmann, is shown in Figure 26. The auxiliary wings or flaps were placed simply on the leading edge of the upper wing opposite the ailerons. When closed, they did not exactly reproduce the original profile shape for constructional reasons. They could be freed for automatic functioning simply by removing a few bolts.

The angle of attack, air speed, sinking speed, longitudinal inclination, angle of glide and elevator deflection were measured in unaccelerated gliding flight. The most important results of these measurements, whose execution and calculation will not here be described in detail, are presented in Figures 27-36.

Figure 27 shows the course of the sinking speed v_s as plotted against the actual dynamic pressure q_w with open and closed slots. The actual dynamic pressure q_w was determined from speed flights over a quadrangular course by a suitable calibration of the indications of the dynamic-pressure gauge.

With the slots closed v_s increases greatly for q_w values smaller than 50 kg/m^2 (10.34 lb./sq.ft.) and greater than 40 kg/m^2 (8.19 lb./sq.ft.), while, with the slots open, the previous course of the v_s curve is preserved up to q_w values of about 45 kg/m^2 (9.22 lb./sq.ft.). Above this point, however, the v_s values increase much more rapidly. Through

the course of the v_s curve, which is reversed for an airplane with the slots open, at small dynamic pressures down to 36 kg/m^2 (7.37 lb./sq.ft.), in such a way that the v_s values increase considerably, with increasing dynamic pressure from 36 to 42 kg/m^2 (7.37 to 8.6 lb./sq.ft.), it is found that the maximum lift of the airplane is reached and even exceeded.

With the slots closed, gliding flights can not be made at $q_w < 41 \text{ kg/m}^2$ (8.4 lb./sq.ft.), because the increased difficulty of operating the airplane, due to the lessened damping and controllability about the longitudinal axis, renders impossible the taking of measurements and the longer maintenance of a given state of equilibrium. With the slots open, however, the damping about the longitudinal axis and the controllability, even in a state of equilibrium with the control stick pulled clear back, were still adequate for long glides at constant dynamic pressure.

In Figure 28, the angle of glide φ , as determined from the air speed and the sinking speed, is plotted against the actual dynamic pressure q_w . The difference in the size of the gliding angle calls for the auto control slot on this airplane, because greater gliding angles can be attained at lower speeds with the slots open. The maximum angle of glide with the slots closed was about 10.5° , while it was 13.5° with the slots open. The airplane was found to be perfectly controllable with the slots open and to be able to maintain

its equilibrium for a long time. At a gliding angle of 10.5° with the slots closed, the damping about the longitudinal axis was appreciably diminished even for slight disturbances of the condition of equilibrium. A long gliding flight could be made only with difficulty.

The course of the elevator deflection β_{HR} , as plotted against the actual dynamic pressure in Figure 29, shows that the maximum elevator deflection with the slots open ($>15^{\circ}$) is greater than with the slots closed (about 10.3°) and at much lower q_w values. The maximum elevator deflection in gliding flight with the slots open corresponded therefore with the maximum deflection of the control stick in the pulling direction.

For determining the maximum angle of attack, the inclination of the direction of flow to the longitudinal axis of the airplane, at a given point in front of the airplane, was taken as the criterion for the angle of attack. The measurements were made with a new instrument developed by the D.V.L. The angle of attack α' (Fig. 30) is here designated as the angle between the direction of flow and the line of symmetry of the instrument at the given point. In Figure 30 the α' values, thus obtained, are plotted against the actual dynamic pressure q_w both with the slots open and with them closed. As was expected, all the measuring points indicate a common course throughout the whole angle-of-attack region, the only differ-

ence being that 3° greater α' values ($\alpha'_{\max} = 20.8^{\circ}$) are obtained at small pressures with the slots open than with them closed ($\alpha'_{\max} = 17.8^{\circ}$).

The angles of attack α , as determined by another method from the gliding angle φ and the longitudinal inclination δ to the flight-path axis, are likewise plotted for comparison in Figure 30 as a curve representing the mean value of the individual measuring points. Since the numerical magnitude of the α values can be rather assumed to be correct, the difference in the course of the two curves can be explained only by the fact that the angle-of-attack meter is still in the region of great variations in the flow and therefore in the region disturbed by the wings. The result is that there is an apparent increase of the actual angle of attack in the region of large q_w values and an apparent decrease in the region of small q_w values. The difference between the angles of attack of the two curves is therefore a criterion for the inclination of the direction of flow at the given point in comparison with a flow parallel to the whole airplane. For the present measurements, however, the absolute magnitude of the α' values is entirely satisfactory as a standard of comparison.

The lift and drag coefficients of the airplane were determined from the measured v_s values and the fineness ratios. The mathematical expression of the experimental

results was based on the conditions of equilibrium for gliding flight without engine. Thereby the fact was disregarded that the propeller thrust with the engine idling still had a definite positive or negative value and that the revolution speed of the propeller at the idling position of the throttle depends on the dynamic pressure. These assumptions are justified, however, since it is here only a question of comparative measurements. In Figure 31 the coefficient of lift is plotted against the coefficient of drag with the slots closed and in Figure 32 with them open. The mean polars are plotted in Figure 33 for comparison. Figures 31-33 show clearly that, up to a certain c_a value, both polars follow the same course throughout. Though the region of the maximum lift above this c_a value is soon reached for the airplane with the slots closed, the maximum lift is considerably greater for the airplane with the slots open and extends over a considerably longer range. Due to the previously mentioned diminished controllability, the maximum lift of the airplane with the slots closed could no longer be utilized. On the contrary, in the gliding flights with the slots open it was possible to fly at several points of the polar above the maximum lift. However, due to the lessening of the elevator effect in this angle-of-attack region and the consequent great variations in the measured dynamic pressures, the accuracy of the measurements was correspondingly diminished. This also explains the relatively

greater scattering of the measuring points in this stalled region of the polar. Nevertheless the airplane was sufficiently controllable and laterally stable, even at these angles of attack corresponding to the maximum elevator deflection in the direction of pulling.

In figure 34 the lift coefficient c_a is plotted against the angle of attack α' for the airplane with the slots open and with them closed. The generally rectilinear course of the relation in most of the range of the angles of attack is here preserved throughout. Greater c_a values are attained at greater angles of attack, however, with the slots open.

Figure 35 illustrates the advantage of the auto control slot for landing on a field surrounded by obstacles. Thus, for example, in gliding from a height of 40 m (131.2 ft.) with the throttle at idling speed, the landing glide is shortened about 50 m (164 ft.) or 24% of the landing glide of an airplane with the slots closed. Care must be taken that the flight characteristics and the controllability of the airplane with the slots open, even at the maximum pull of the control stick, fully satisfy the requirements.

The knowledge of the poor controllability of most airplanes at large angles of attack is the principal reason why all airplanes are flown with a smaller utilization of their working range than would be feasible even with regard to safety. The use of the auto control slot contributes considerably in this

case to safety in landing and to the more complete utilization of the working range of the airplane.

In conclusion I will add a few words regarding the lateral-stability tests now being made for the purpose of determining the effect of the Handley Page auto control slots on the lateral stability and controllability at large angles of attack. The index for the behavior of an airplane at large angles of attack is the sign and magnitude of the damping about the longitudinal axis in disturbances of the equilibrium. A criterion for the magnitude of the damping is the magnitude of the angular velocity about the longitudinal axis due to sudden disturbances of the equilibrium. Disturbances of the equilibrium of known magnitude were produced by suddenly releasing sand bags from the tips of the lower wing by means of an electrical device.

The angular velocity of the airplane about its longitudinal axis was measured in terms of the time by determining, with the aid of a rigidly mounted motion-picture camera with the field of vision in the direction of the longitudinal axis backward over the tail, the position of the airplane with respect to the horizon both before and after producing the rotation. The exposures were 8 to 9 per second. The measurements were made in the region of large angles of attack at different dynamic pressures of gliding flight with the engine throttled to idling speed.

The first results of these measurements are shown in Figure 36, where the angle of roll of the airplane about its

longitudinal axis, with respect to the horizon, is plotted against the time for various gravity moments. The previous measurements show that, within the angle-of-attack range considered, the angular velocity about the longitudinal axis is constant after the beginning of the motion, and that no appreciably greater accelerations are produced.

Though these investigations have not yet been completed, they have, nevertheless, shown smaller angular velocities of the airplane about its longitudinal axis with the slots open than with them closed. No detailed report of these comparative measurements can yet be made, however. It is only intended to indicate here the methods followed by the D.V.L. and the way the measurements are made, in order to determine the behavior of the airplane as regards controllability and lateral stability.

In reply to the question asked by Mr. Focke, it may be remarked that the above briefly described stability measurements concern only the initiation of a motion, which may be regarded as a practically pure rotation about the longitudinal axis at the large angles of attack and at the rotational angles investigated. The results do not apply to the part of the motion, during which an additional rotation takes place about the vertical axis due to the changed angle of attack of the wing tips.

H. Focke.- The stability of an airplane about all three axes has always been the most important problem aside from that of dynamic lift. It seems strange, therefore, that the very one of the three stabilities exhibiting the most dangerous phenomena, namely lateral stability about the longitudinal axis, has been conspicuously neglected. This problem is very difficult, because any change in the angle of attack may effect a rapid and considerable change in the lateral stability alone.

The restoring moment (if present at all in the positive sense), the aileron effect and the damping moment disappear very suddenly at a certain angle of attack. This is generally followed by autorotation or spinning, due to the separation of the air flow from the sinking wing with its increasing angle of attack. Any action of the ailerons only makes the matter worse, since the sinking wing does not gain in lift but suffers a braking effect (moment of yaw in the wrong direction). In the region of the course stability and pitching stability no phenomena occur, which are even approximately so dangerous as those described in connection with longitudinal stability. There were two main reasons for this surprising neglect of the lateral stability.

The first is external and an outcome of the military development. Before the war we had a laterally very stable airplane in the "Taube." Since, during the war, the performance requirements preceded all others, there arose the yet not entirely abandoned fundamental error, that lateral stability of

an airplane necessarily involves poor aerodynamic qualities as regards lift and drag. Lateral stability was deliberately abandoned, since, at that time, there was and could not be any clear conception of the importance of this retrogression.

The second reason is internal and can alone explain why the situation still remained the same almost ten years after the war. Technical men of today are inclined to neglect everything that can not be immediately figured out mathematically, instead of first seeking a qualitative solution by means of the laws of physics. Lateral stability baffles calculation to a much greater degree than longitudinal stability.

The writer has repeatedly called attention to the urgent need of a high degree of lateral stability (Z.F.M. 1928, page 545). A very large proportion of the worst airplane accidents have hitherto been caused by the loss of lateral stability in stalled flight. Moreover, there are, even now, many airplanes which lack lateral stability in normal flight and can be flown only because the damping about the longitudinal axis is always great at normal angles of attack.

The Focke-Wulf company has long endeavored to make at least its commercial airplanes so stable laterally that a) stalling would cause only loss of altitude and not lateral rotation. Moreover, the goal was also b) absolute security against spinning induced by rudder deflections. The Focke-Wulf wing is similar in shape to that of the Taube with its upward-

bent tips (Fig. 37). It was important, however, to obtain stability:

1. Without worsening the aerodynamic qualities as compared with other good modern wings, in order not to impair the flight performances.
2. Without movable mechanisms, in order not to introduce new sources of disturbance.
3. Without weight increase.
4. Without any moment of yaw in the wrong direction when the ailerons are deflected.
5. With adequate aileron effect in stalled flight.

Since 1924 all the Focke-Wulf commercial airplanes have met requirement a with the fulfillment of conditions 1 to 5. By reason of improvements, which can not here be fully described on account of patent rights, requirement b, absolute security against spinning, was also successfully met in 1929 by surprisingly slight changes, likewise with the fulfillment of conditions 1 to 5.

Here therefore we have a rare instance of an important effect being produced by formative measures without any consequent disadvantages. On the other hand, it must not be assumed that every thick wing will have equally good characteristics.

The following report of the D.V.L. (German Aeronautic Institute) describes the phenomena observed on the spinproof Focke-Wulf A 28 "Habicht." Of especial interest is the absolute independence of the spinproofness of the location

of the center of gravity, which was shifted aft to an exceptional degree (39%).

"Lateral Stability of the Focke-Wulf A 28"

"The Focke-Wulf A 28 was tested by the D.V.L., June 6, 1929, with respect to its flight characteristics. The D.V.L. test pilot Schüz found that this airplane exhibited surprising lateral stability not only in normal flight but also in stalled flight.

"On account of the importance of this result, the D.V.L. arranged with the Focke-Wulf Co. of Bremen for another flight test of the airplane, in order to secure a qualitative verification of the above-mentioned results. In this test, which took place Jan. 10, 1930, the following data were obtained:

"Flight 1."— The flight was made with the greatest possible advance of the center of gravity (32.1% with respect to t_m , at a distance of $2b/3\pi$ from the middle of the fuselage, and 33.8% with respect to the wing chord at the fuselage).

Trimming: Fuel (forward tank only)	50 kg (110.23 lb.)
Oil tank	10 " (22.05 ")
Pilot	76 " (167.55 ")
Baggage room	0 "

The airplane proved extraordinarily stable laterally in both normal and stalled flight and had a fully adequate aileron effect at an angle of attack corresponding to an indicated

air speed of 65 km/h (40.4 mi./hr.). It was not possible to throw the airplane into a spin.

"Flight 2.— This flight was made with a mean position of the C.G. (35.6% with respect to t_m , at a distance of $2b/3\pi$ from the middle of the fuselage, and 37% with respect to the wing chord at the fuselage.

Trimming: Fuel (forward tank only)	50 kg	(110.23 lb.)
Oil tank	9 "	(19.84 ")
Pilot	76 "	(167.55 ")
Baggage room	55 "	(121.25 ")

The result was the same as in flight 1. No perceptible changes occurred in the behavior of the airplane as compared with flight 1. No spin could be developed.

"Flight 3.— This flight was made with almost the farthest possible rearward position of the C.G. (37.5% with respect to t_m , at a distance of $2b/3\pi$ from the middle of the fuselage, and 39% with respect to the wing chord at the fuselage).

Trimming: Fuel (front tank only)	50 kg	(110.23 lb.)
Oil tank	8 "	(17.64 ")
Pilot	76 "	(167.55 ")
Baggage room	90 "	(198.42 ")

The result was the same as in flights 1 and 2. No spin could be developed even at this position of the C.G.

"According to the results of these tests, the lateral-stability characteristics of the Focke-Wulf A 28 corresponded

approximately to those of airplanes fitted with Handley Page auto control slots. The fact that the behavior of the airplane in stalled flight was not affected by the location of the C.G. seems to indicate that it was due to the shape of the wing. The attainment of adequate lateral stability and controllability in stalled flight is one of the most important problems as regards safety."

The present possibility of safe flight in the stalled condition yields further very important results. It is possible to fly with a very poor fineness ratio near the maximum lift and hence make a steep landing glide (about 1:4) at a minimum speed to a narrow field. The spinproof Focke-Wulf "Habicht" has, e.g., a minimum speed of 62 km/h (38.5 mi./hr.) with a maximum speed of 179 km/h (111 mi./hr.). This enables a sinking speed of 4 - 5 m/s (13 - 16 ft./sec.) and, although present-day landing gears can not stand a direct landing in this manner, it would not be very difficult to adapt them to it. It would require twice the travel of the springs, about 40 cm (16 in.) instead of 20 cm (8 in.).

It should also be noted that the spinproofness of the Focke-Wulf airplane has nothing to do with its stallproofness. This follows from the fact that a spin can not be developed when very great angles of attack are produced. It would certainly be desirable to avoid stalling altogether. On an ordinary airplane it is not generally possible, at the maximum lift, to eliminate the elevator effect suddenly enough, if it is to suffice for

normal flight. Hence this method is feasible only for "Ente" airplanes, where the very powerful elevator effect near the region of maximum lift drops automatically and almost instantly to zero.

The entire development of the Focke-Wulf wing, due to lack of funds, has hitherto taken place almost without quantitative measurements of the lateral stability. It is very much to be desired that the D.V.L. should now be given the opportunity to make such tests on an actual airplane, as have already been made for the Handley Page wing with similar although not so comprehensive aims, because the results of wind-tunnel tests can hardly be utilized in practice, on account of the noncomputable characteristic effects which occur in the immediate vicinity of the maximum lift.

Professor Hoff.— I did not quite understand the unit weight indicated by Dr. Lachmann for a slotted wing. What relation does this unit weight bear to the unit weight of the whole wing? This relation might furnish indications regarding the practical possibility of using slotted wings. How great is the elevation of the trailing edge of the auxiliary flap? The pictures shown by Dr. Lachmann did not indicate this clearly enough.

In the many-jointed mechanism of the auxiliary wing no damping of the motion of the flap is necessary, according to Dr. Lachmann, while a flap with a straight guide is difficult to shift from one position to another. Since the straight-guide

mechanism has certain structural advantages, it is desirable to know the amount of the damping vainly resorted to with such devices.

Dr. Lachmann very graciously referred to the work of the D.V.L. which had thus far been done in the realm of slotted wings. This work has been small, because until recently there was no airplane with slotted wings at our disposal. We hope the D.V.L. will be able to conduct further researches in this very interesting field.

The task of the D.V.L. is to investigate thoroughly the various possibilities of eliminating dangerous flight conditions, in order to balance the advantages and disadvantages against one another. The Focke-Wulf "Habicht" was flown by the D.V.L. in a series of type tests, but no static tests were made. This airplane has the favorable characteristic that it can not be thrown into a spin. It is hoped that the D.V.L. will get one of these airplanes for static testing.

H. Herrmann.-- Land tests of seaplanes have been made, in which not the lowest possible landing speed of the given airplane, but the mean landing speed for ordinary pilots was determined. This was 15 to 40% above the actual minimum speed. Now if a normal twin-float seaplane is flown at its maximum coefficient of lift, it will strike the water at a greater angle of attack than the float is adapted to. The result is 3 or 4 violent oscillations on the water, which the pilot can not

prevent. If the landing is made at a higher speed and smaller angle of attack, these rocking motions are not produced. They are caused by the floats and are common to all twin-float seaplanes known to me.

Take, for example, the landing of a seaplane in a rough sea. At first it grazes the crests of the waves and loses speed. In a normal landing of a modern seaplane nothing happens at this time. At the moment of immersion, however, the seaplane has a sinking speed with respect to the water, which, aside from the now low horizontal speed, depends only on the size of the waves and the size and shape of the floats. The pilot can change nothing at all. Even the constructor can do hardly anything. He can vary only the absolute size of the seaplane. E.g., the hull of the "Do X" covers two wave lengths in seaway 4, while an ordinary float seaplane of 2 to 3 metric tons flying weight covers only about 1/3 of a wave length. Experience has shown that the damage is done at the moment of immersion. The only protection is afforded by the great strength or the shape of the float bottom. Reduction of the landing speed does hardly any good, since immersion occurs at about 40% of the same. In the great diversity in the nature of the seaway, it matters very little whether it is 40% of 100 or of 80 km/h, (49.7 mi./hr.).

I built two seaplanes with slotted wings before these facts were known. The slotted wings always worked perfectly. Their extra weight was perfectly allowable. In landing on quiet water the landing angle was too great for the visibility. No sea test

was made. If one were made, however, the landing angle would make itself felt not only in the first contact but also on immersion, after which every seaplane type would assume an approximately horizontal position. The large angle of attack required for the action of the slotted wings is lacking.* For these reasons I no longer use slotted wings on seaplanes. I may possibly try them again on some type, since they always functioned perfectly. Regarding the use of slot control, I venture to refer to my remarks of a year ago during the discussion of Hübener's paper. I then said that one should be able to obtain the same result in another way, namely by giving a suitable form to the wing tips. It seems quite possible that within five or ten years, other devices may be found to prevent any undesired spinning. Each such device will probably be used in the particular field for which it is best suited. Slot control seems to be better adapted to military airplanes, while the Focke-Wulf wing is probably better adapted by its unusual lateral stability to commercial airplanes. To the best of my knowledge, there is no large commercial aviation company

*In his concluding remarks the speaker mentions that the second seaplane had slotted wings with only a leading-edge slot. More careful consideration shows, however, that the slight variations in the angle of attack in this case (about $22\text{--}24^\circ$ as against 18° otherwise) are of no practical consequence. Villiers made his tail floats with unusually small displacement and had to accept consequent disadvantages on the water, which are intolerable on the Baltic and North Sea. He probably hoped to get more benefit from the slotted wings as a consequence of elevating the tail.

operating 20 or more airplanes, which has equipped even 10% of them with slotted wings.*

Georg König.— I know of an airplane, which was flown horizontally at a very large angle of attack with the throttle wide open. It was in the spring of 1914, and the airplane was a biplane of 9.5 m (31.2 ft.) with a sweepback of 15° , a wing gap of 1.55 m (5.09 ft.) and a positive stagger of 0.7 m (2.3 ft.). Without slipping over the wing, it flew at an angle of attack of 27° , which was accurately determined by the observation that the wing struts assumed an exactly vertical position.

Dr. Lachmann in his concluding remarks first thanked Dr. Pleines in particular for his report, which constituted a valuable supplement to his own lecture. He also thanked the D.V.L. in general for their systematic investigation of slotted wings, which had hitherto been rather neglected in Germany.

Such fine exact flight tests of slotted wings, as Dr. Pleines had made, stood alone and perhaps were made possible only by the rare union, in his person, of the airplane pilot and of the engineer schooled in exact scientific methods. On

*With the limitation that the company must operate at least 20 airplanes, I wished to exclude the "Imperial Airways." According to Jane's "All the World's Aircraft" 1929, they have 26. After deducting 3 flying boats lost in the Mediterranean, they still have 23, though I had estimated them at only 20. It remains true, however, that large companies, like the German "Luft-Hansa," the Latécoère lines or the great American lines with more than 100 airplanes, make no use of slotted wings worth mentioning.

the other hand, only such flight tests, recorded by perfect instruments, could furnish the data for the definite and accurate determination of flight characteristics. The judgment of a single pilot as based on his feeling, has only a limited qualitative value, and even the mean result of the conclusions of several pilots can never be accepted as a perfect quantitative criterion, for there is often such a "scattering" between plus and minus as to render impossible the finding of any mean value.

In detail he remarked regarding the experimental results obtained by Dr. Pleines, that the elevator on the tested airplane was apparently not effective enough, since a maximum angle of attack of only 21° could be obtained with the control stick pulled clear back. He suggested increasing the angle of setting of the stabilizer, in order to attain still greater angles of attack and steeper angles of glide. The differences obtained in the polars are remarkable and show that not only the flight characteristics, but even the performances of an airplane of unusual stability and fineness can be improved.

Regarding the continuation of the tests for the determination of the lateral damping, he suggested the rolling motion be initiated by dropping ballast and measuring the time required to eliminate the rolling motion by means of ordinary ailerons and also with the aid of slots.

To the questions of Prof. Hoff, Dr. Lachmann replied that

the unit weight of the auxiliary wing mentioned by him and constructed for a large commercial airplane was 6.72 kg/m^2 (1.38 lb./sq.ft.), or, since the chord of the auxiliary wing is $1/8$ the chord of the main wing, the weight increase of the portion of the main wing fitted with auxiliary flaps is 0.83 kg/m^2 (.17 lb./sq.ft.). The unit weight of the whole cell is 8.3 kg/m^2 (1.7 lb./sq.ft.). The increase in the unit weight is accordingly about 10% for the portion of the main wing fitted with the auxiliary flaps. The airplane was a biplane with a relatively low wing loading of 50 kg/m^2 (10.34 lb./sq.ft.). Since the utilization of the material in the construction of the auxiliary wing was not carried very far for structural reasons, it is assumed that the unit weight of the auxiliary wing does not increase in proportion to the unit load, so that the percentile increase in the unit load due to the auxiliary flap is probably less for airplanes with high breaking loads per m^2 than for the given example.

He said that the elevation of the trailing edge of the auxiliary flap is always very small, amounting to only a few millimeters.

The sudden projection of the auxiliary flap from its position of rest with the straight guide could be avoided without additional damping by using a curved guide. Generally speaking only air dampers were used, as oil dampers were very liable to freeze.

The Handley Page firm is very grateful to the D.V.L. for the thorough testing of the slotted wing and will support further research work in every way. A new improved auxiliary wing together with a slot-controlling device operated by the aileron have already been put at their disposal.

Regarding the statements of H. Focke, Dr. Lachmann remarked that he had anticipated his address with much interest. He regretted that Mr. Focke had presented no quantitative data regarding the characteristics of the "Habicht" in stalled flight. It could hardly be assumed that a firm, which, according to Mr. Focke, had for years been busy improving the lateral stability of its airplanes, should dispose of no exact experimental data, e.g., of polars obtained from flight or wind-tunnel tests, from which to determine the maximum angle of attack and the beginning of the separation of the air flow and also the course of the gradients $dC_n/d\alpha$ or $dC_a/d\alpha$, which tells the specialist all he wishes to know regarding the stability in stalled flight.

He took issue with Mr. Focke's statement that the lateral stability was not amenable to mathematical or empirical treatment and referred to the voluminous German* and English**

*R. Fuchs and W. Schmidt, "Luftkräfte und Luftkraftmomente bei grossen Anstellwinkeln und ihre Abhängigkeit von der Tragwerksgestalt," Z.F.M., Jan. 14, 1930, pp. 1-12.

**"The Lateral Control of Stalled Aeroplanes. General Report by the Stability and Control Panel." Reports and Memoranda, No. 1000, 1926.

literature on the subject of autorotation and stability in stalled flight.

It is not at all true that data obtained from wind-tunnel tests afford no basis for determining the behavior in flight on account of the effect of the characteristic value. Correctly flown polars (with engine stopped) agree very well with the wind-tunnel polars even for thick wing profiles.*

From the general statements of Mr. Focke and the purely qualitative report of the D.V.L. it may be concluded that nothing was determined aside from the speed and the location of the C.G. and that all the statements regarding the lateral stability and aileron effect in stalled flight, the angle of glide, etc., were based on feeling and visual estimation.

On thick-winged monoplanes one is subject to optical illusions in estimating the angle of attack with respect to the flight path. The Fokker monoplane, on the basis of skillful demonstration, was considered absolutely spinproof, laterally stable and controllable in stalled flight, until the mysterious characteristics were thoroughly investigated in England with the aid of systematic tests. The results were published in Reports 1228 and 1236 of the 1928 British Reports and Memoranda, "Full Scale Control Tests on Fokker F. VII -

*"Full Scale Measurements of Lift and Drag of the Fokker F.VII - 3M Monoplane," by J. K. Hardy, B.A., British R&M No. 1096, 1927.

"3 M Monoplane" and "The Control of the Fokker F. VII - 3 M Aeroplane." From the latter report the following sentences are quoted.

"There appears to be no doubt that when the machine is really stalled it is subject to the same dangers which are present in conventional British aeroplanes. Thus if either of the wings drop, the controls are quite inadequate to restore equilibrium without a reduction of incidence involving a dive and gain of speed.

"The results of wind tunnel experiments are in agreement with this conclusion, since they give, in essentials, results similar to those for conventional British aeroplanes, with the exception, however, that they show unusual stability for small rates of roll. The wind tunnel experiments suggest, in fact, that the aeroplanes might be unusually easy to fly stalled whilst it is on an even keel, but should be no freer from danger than other machines once a serious roll or yaw has commenced.

"In respect of danger from stalling, the matter may be summarized by the statement that the danger following a stall on a Fokker is no less than that upon other machines, but the probability of the stall occurring may be less."

Dr. Lachmann said that he was inclined to hold the same opinion regarding the Focke-Wulf airplane as that expressed in the British report regarding the Fokker F.VII, so long as Mr. Focke does not furnish conclusive proof that his wing is not

subject to autorotation at angles of attack of 25 to 30°, and that an airplane equipped with his wing and with efficient horizontal and vertical control surfaces can not be made to spin.

He did not deny the importance of the method adopted by Fokker and Focke-Wulf for avoiding the danger of stalled flight, namely by reducing the dimensions of the elevator and all the other control surfaces with simultaneous maximum damping about all three axes.* This method does not absolutely eliminate, however, the danger of autorotation and can be used only on airplanes where a reduction in the controllability and maneuverability is known to be permissible. This point was not mentioned by Mr. Focke. Any reduction of the controllability is not only a disadvantage, but also dangerous, namely when the airplane is forced into a full stall by powerful external influences (gusts).

In making an aerodynamic analysis of autorotation, we come upon phenomena in the boundary layer (separation due to increase of pressure and loss of energy), which can be avoided only by secondary means (slotted wings, increase of energy or removal of boundary layer by suction) and not simply by changing the shape.

Dr. Lachmann said that his utterances are not to be construed either as a one-sided propaganda for slotted wings

*Even a fully stalled airplane, when equipped with slotted wings can be thrown intentionally into a spin only when it has an efficient rudder.

or as an attack on the meritorious labors of Focke who had the same goal in view, namely, increasing the safety of flight. In the interest of progress it is necessary, however, to have a clear conception of the quantitative limits of the Focke principle, and he thanked Mr. Focke for his stimulating and valuable remarks.

Regarding Mr. Herrmann's statements, Dr. Lachmann remarked that Mr. Herrmann had used on the previously mentioned seaplane only a leading-edge flap without any connected aileron which could be pulled down. This device can be used only on seaplanes, since it makes it possible to attain the maximum lift of the wing without excessive incidence of the longitudinal axis of the airplane. When a leading-edge flap is used without aileron, the angle of attack corresponding to the maximum lift is said to be $25-28^{\circ}(!)$. It is obviously impossible to utilize so large an angle in landing. When an aileron is used, the incidence of the longitudinal axis for the maximum lift of the slotted wing is about the same as for a conventional wing.

All the new types of the "Imperial Airways" (namely the new Argosy's and the Handley Page 42) are provided with the auto control slot, because this company is convinced of its practical importance. It has not been generally adopted by other companies, due partly to lack of conviction and partly to lack of funds.

Subsequently Added

The general pitching movements ("porpoising") mentioned by Mr. Herrmann, which occur in landing at maximum lift, had been previously observed on twin-float seaplanes in England.

According to a personal communication from a well-known British seaplane test pilot, this trouble has been remedied by a suitable V shape of the bottom of the float, correct position of the steps, and the correct position of the floats with respect to the fuselage and the wing chord on all recently built British seaplanes.

Figures 38-39 show a twin-float seaplane equipped with slotted wings. It is the Handley Page "Harrow" designed and built by Short Bros., Rochester. According to the experiences of the Handley Page firm, this seaplane represents not only the most successful application yet of slotted wings to seaplanes, but also one of the most successful applications of the slotted wing anyway. This seaplane has automatic stabilizing and lifting slotted wings actuated by gears, which, in opening, simultaneously deflect an aileron downward.

With the slot closed, the take-off speed is quite high, but, with the slot open, the seaplane can take off almost immediately after rising on the step at a relatively low speed and a large angle of attack. Alighting with the slot closed takes place in the conventional manner, in that the seaplane alights on the step without subsequent pitching.

With the slot open, not only the sinking speed is lower, but the horizontal speed on alighting is about 16 km/h (10 mi./hr.) less than with the slot closed. The run after alighting is very short. The stern of the float touches the water first, which naturally produces a tendency to throw the airplane forward with a certain impetus on the bow of the float. The unpleasant pitching movements mentioned by Mr. Herrmann do not occur however.

On the basis of these tests, the Handley Page company has come to the conclusion that the use of slotted wings is more advantageous on seaplanes than on landplanes, provided the floats are correctly designed and adapted to the altered conditions.

Automatic stabilizing slots are especially advantageous for flying boats, since many flying boats have the unpleasant habit of "jumping" in a rough sea, before attaining their take-off speed. There is then great danger that they will lose their balance and slip over the wing.

Regarding the statements of Mr. König, Dr. Lachmann remarked that a strongly staggered biplane resembles in principle a slotted wing with a greatly enlarged auxiliary flap, especially when the upper wing has a smaller angle of attack than the lower wing. It is also probable that the great yawing stability, due to the strong sweepback, facilitated flight at a large angle of attack. It is surprising that it was possible at that time to

fly level with full gas at so large an angle of attack.

In conclusion Dr. Lachmann thanked the audience, and especially the participants in the discussion, for their great interest.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

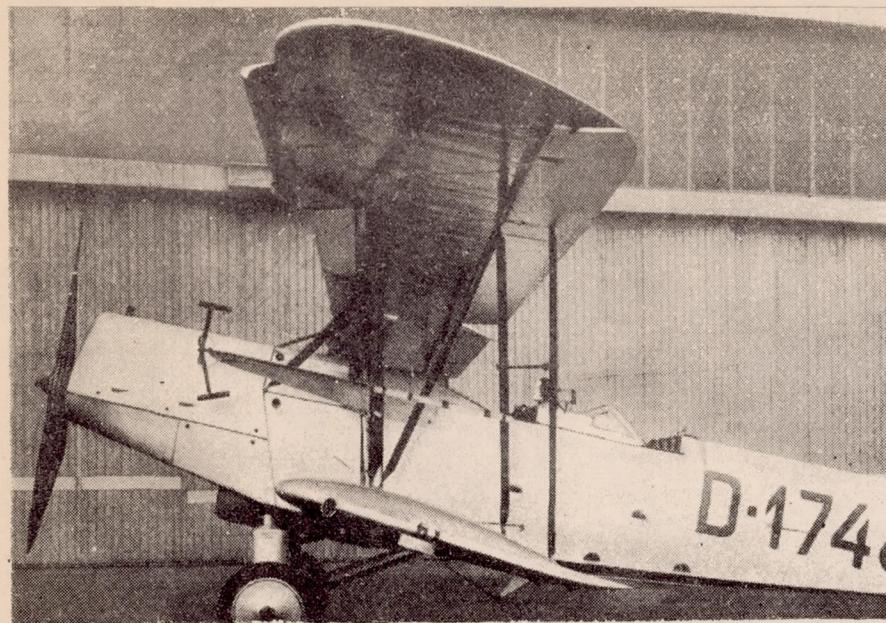
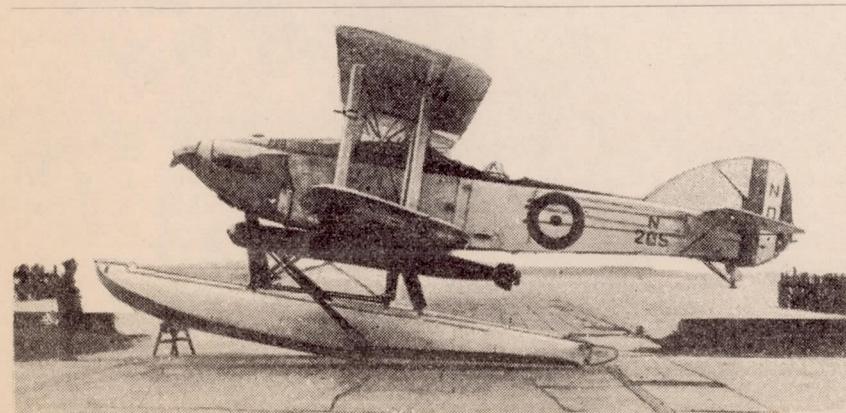


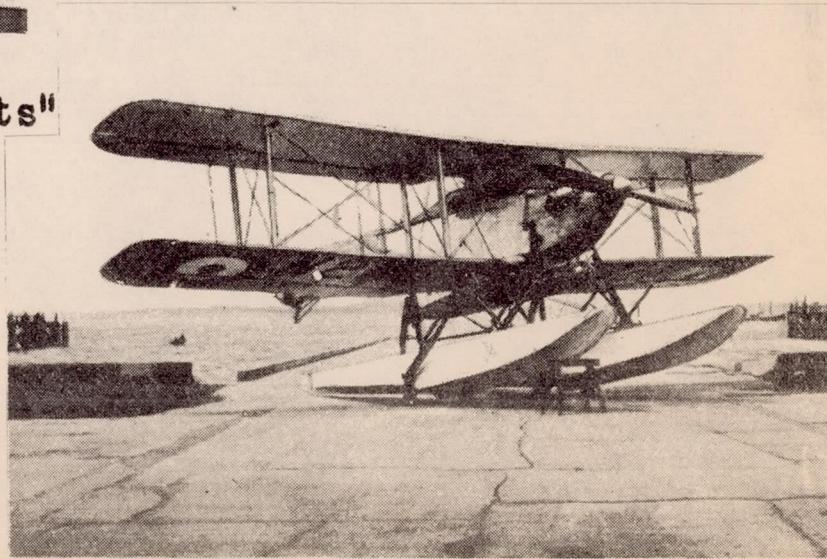
Fig. 26 Albatros L 75 Ass equipped with Handley Page "auto control slots"



Figs. 38, 39 Handley Page "Harrow" with slotted wings.



Fig. 37 Focke-Wulf airplane.



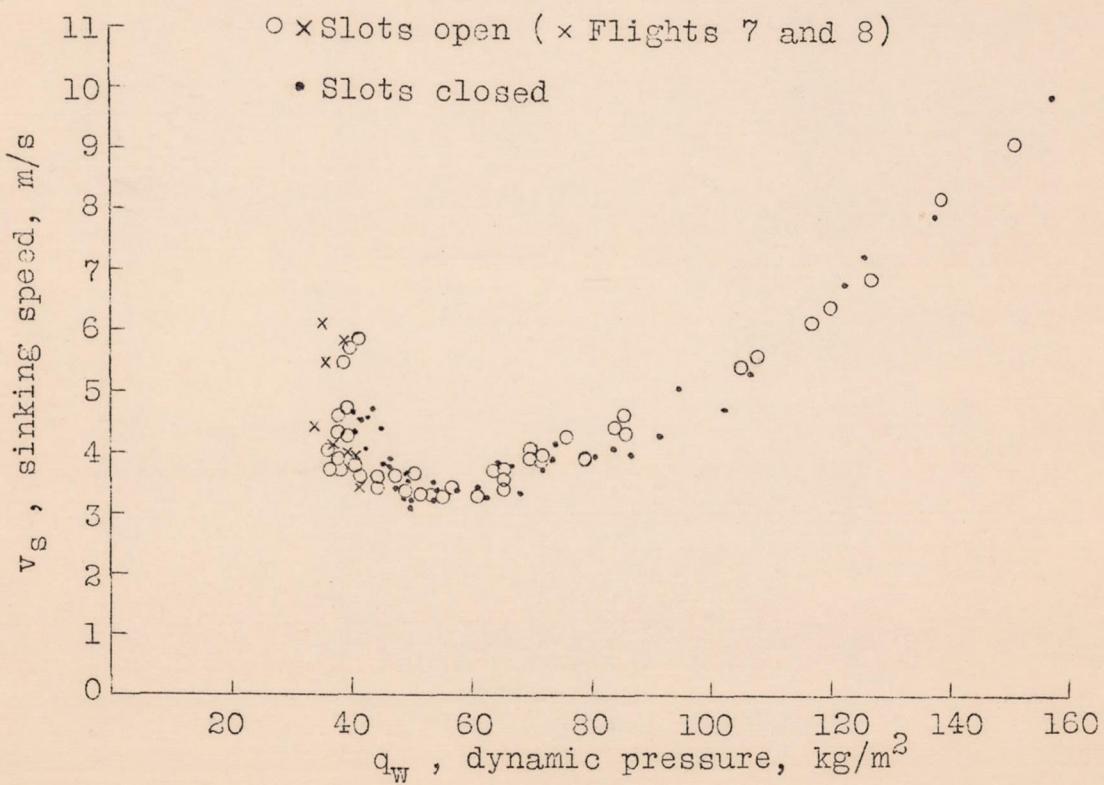


Fig. 27

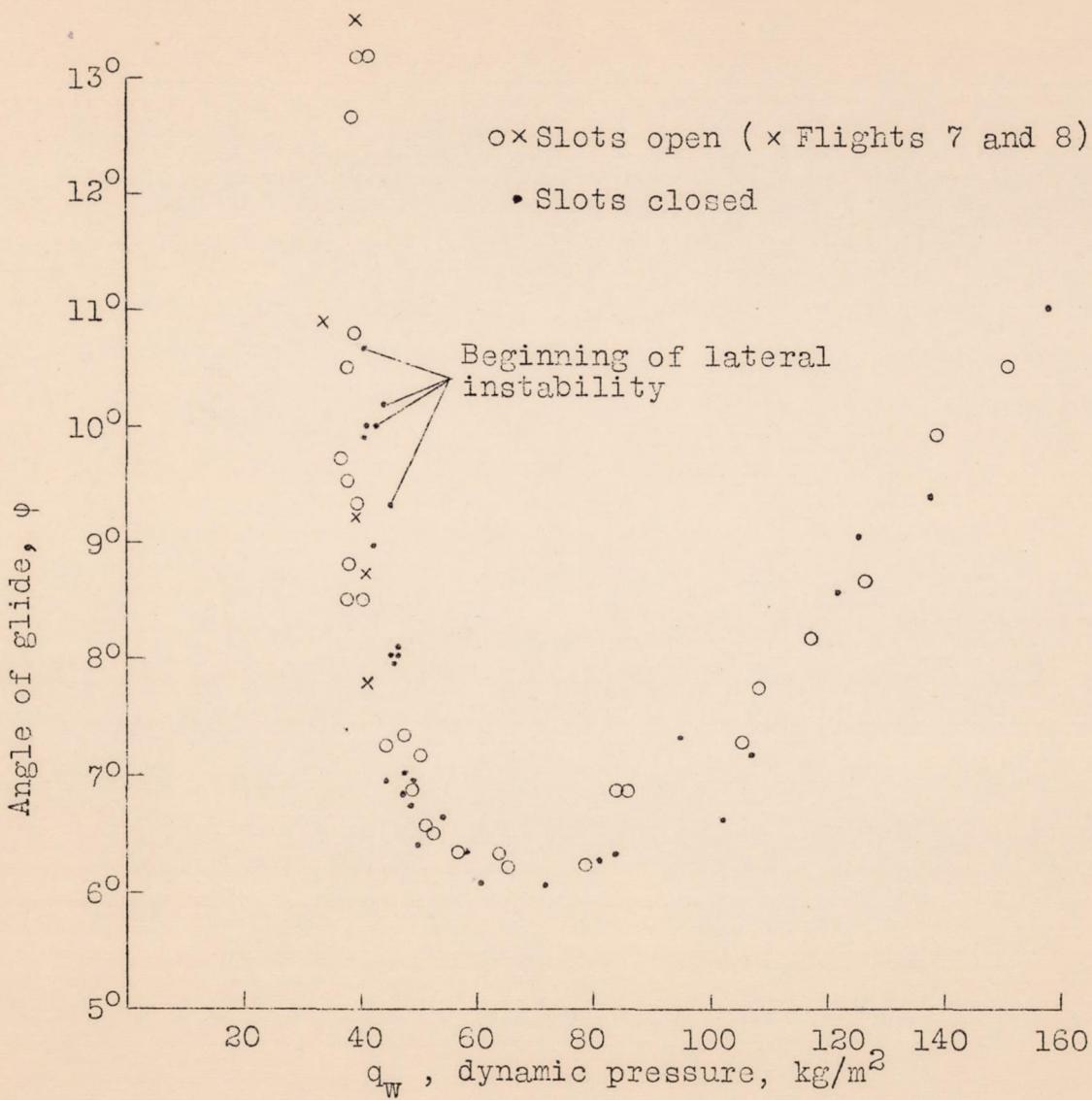


Fig. 28

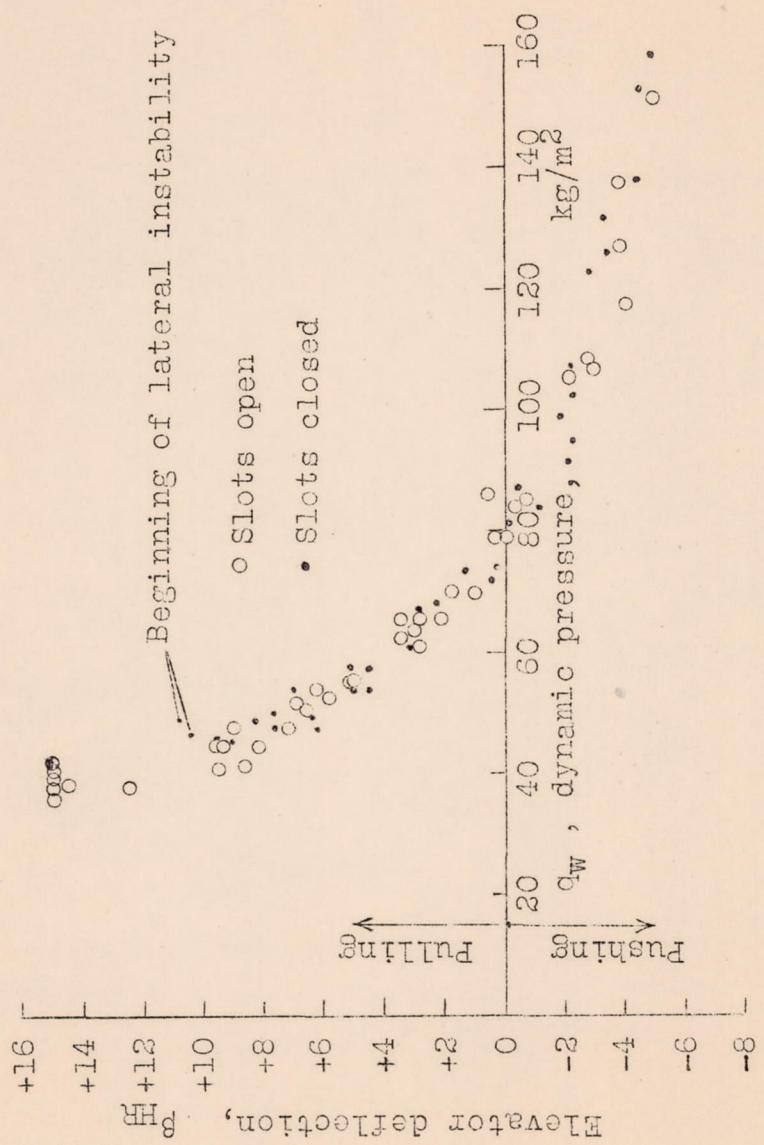


Fig. 29

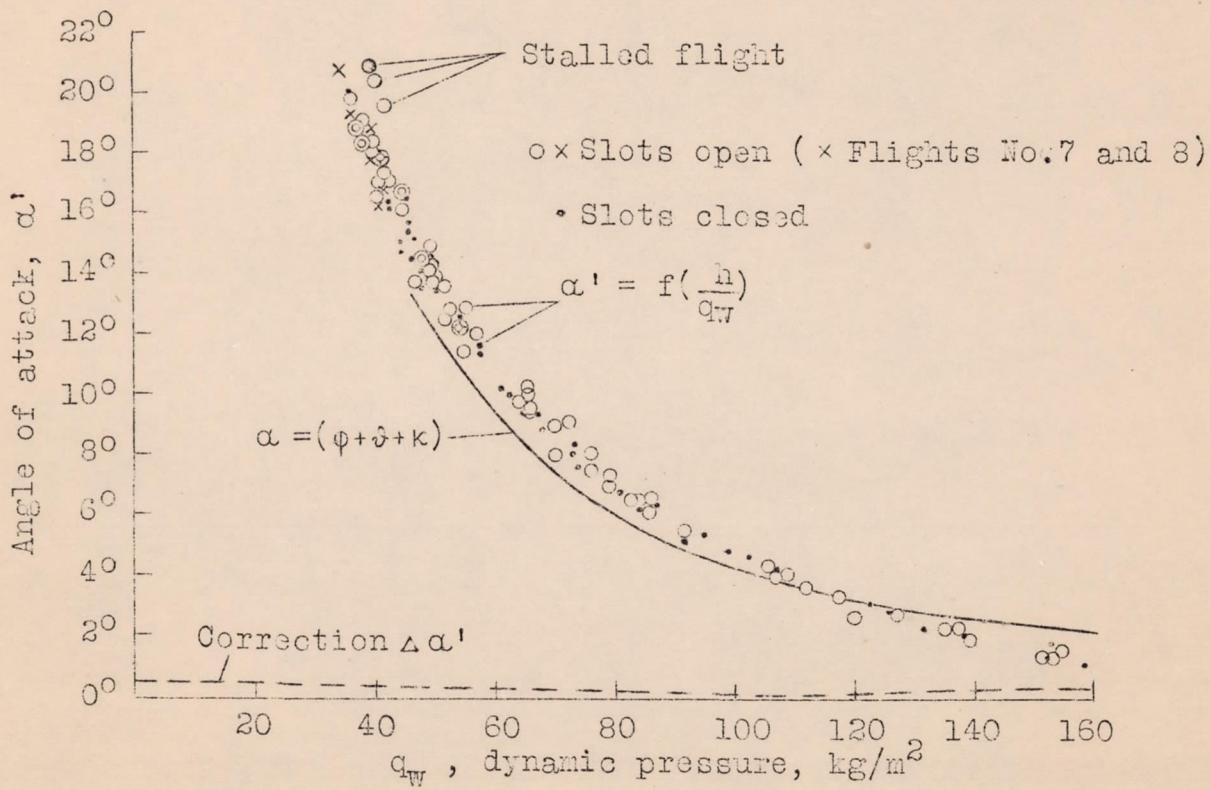


Fig. 30

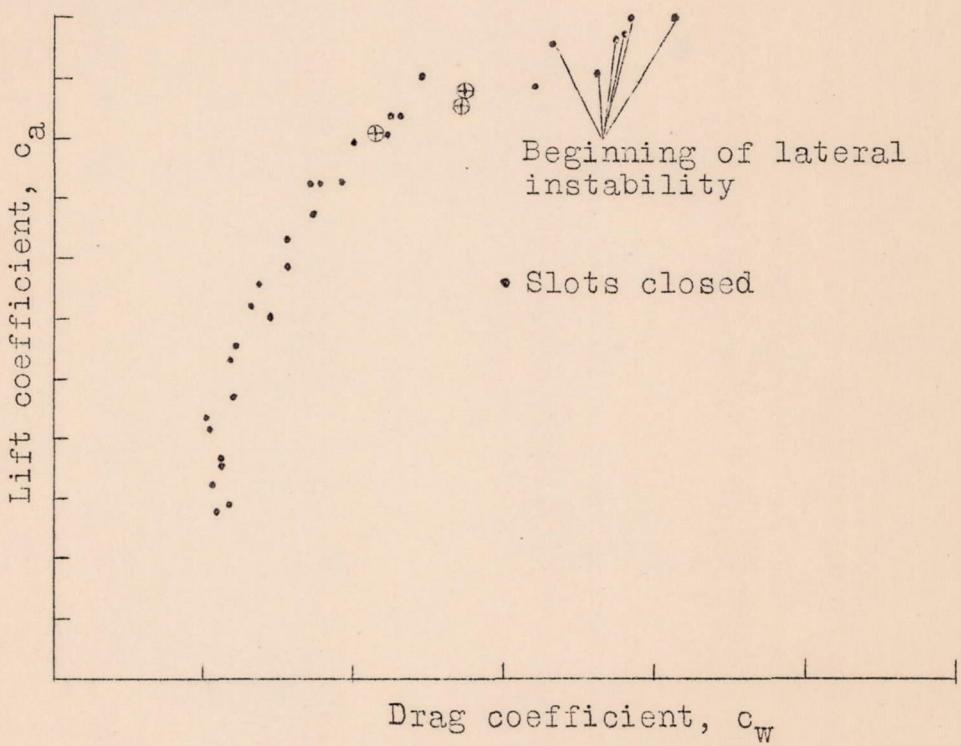


Fig.31

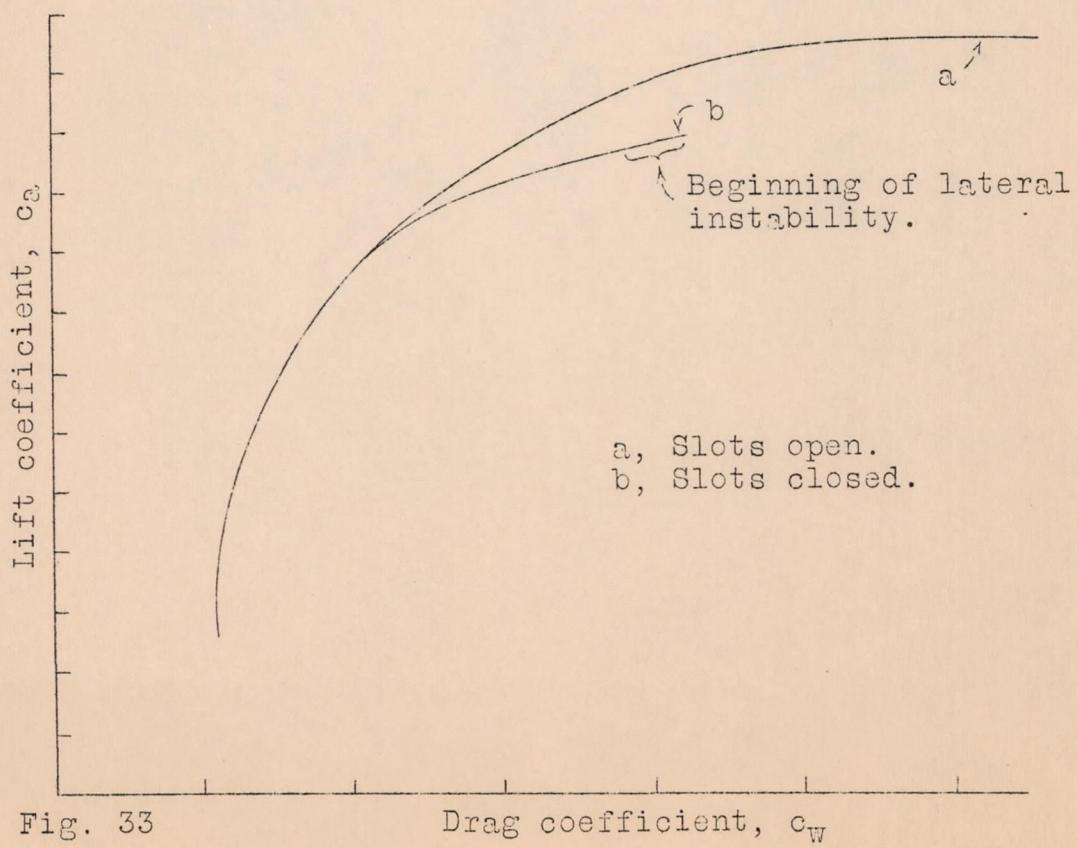
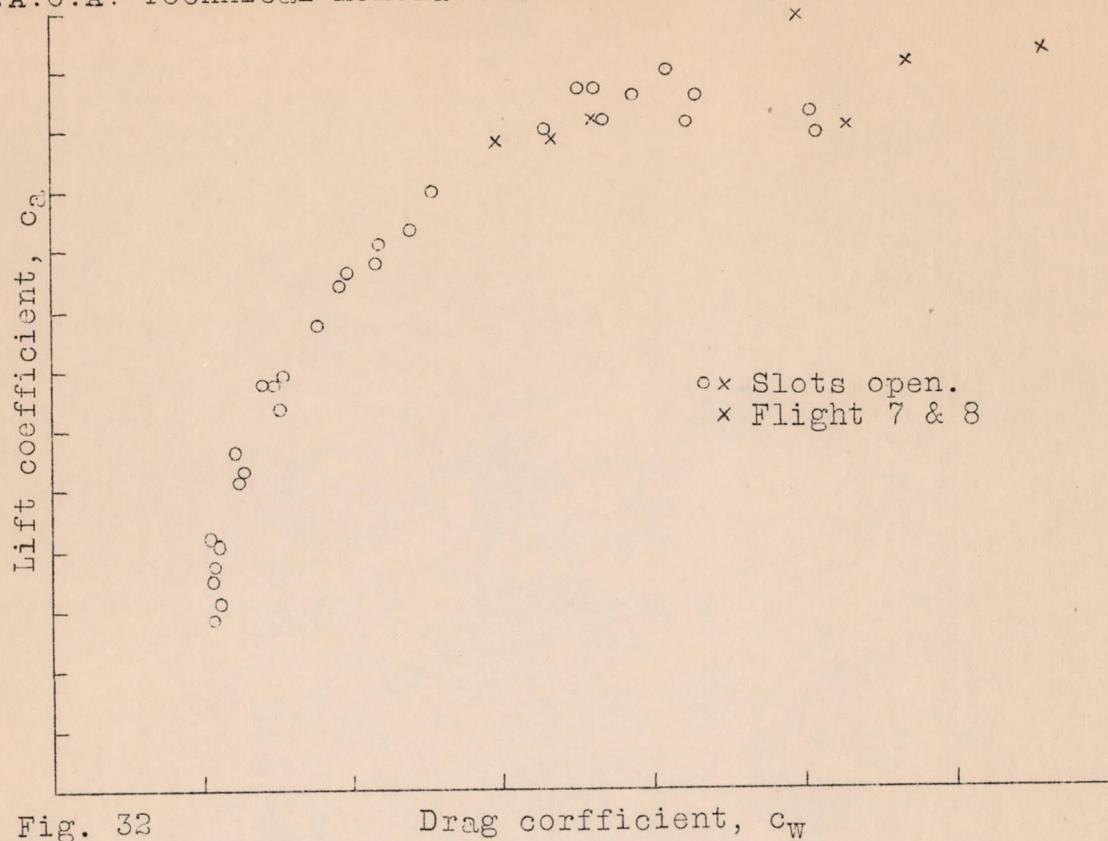
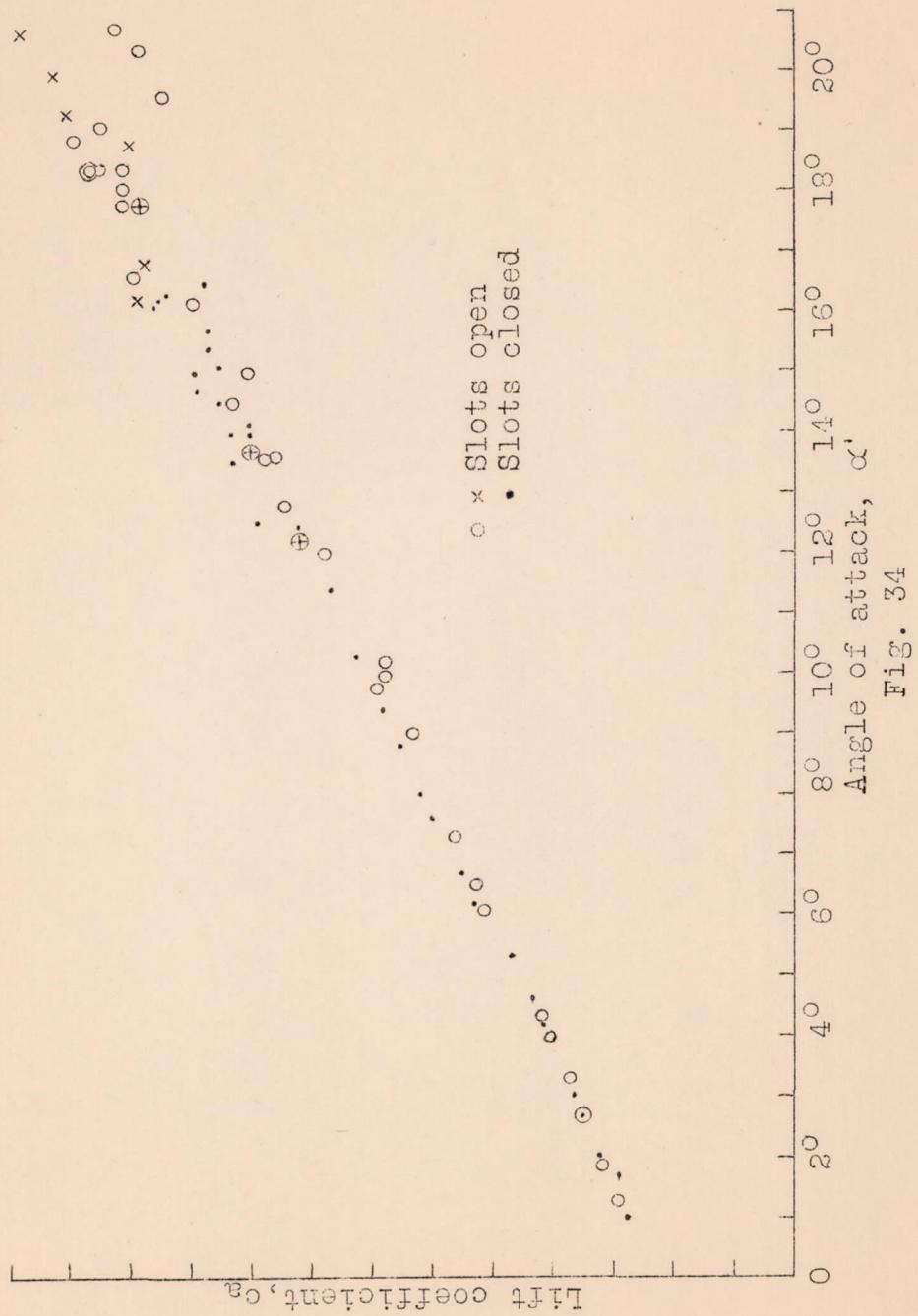


Fig. 34



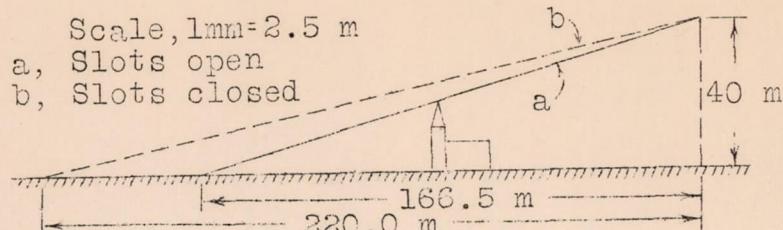


Fig. 35

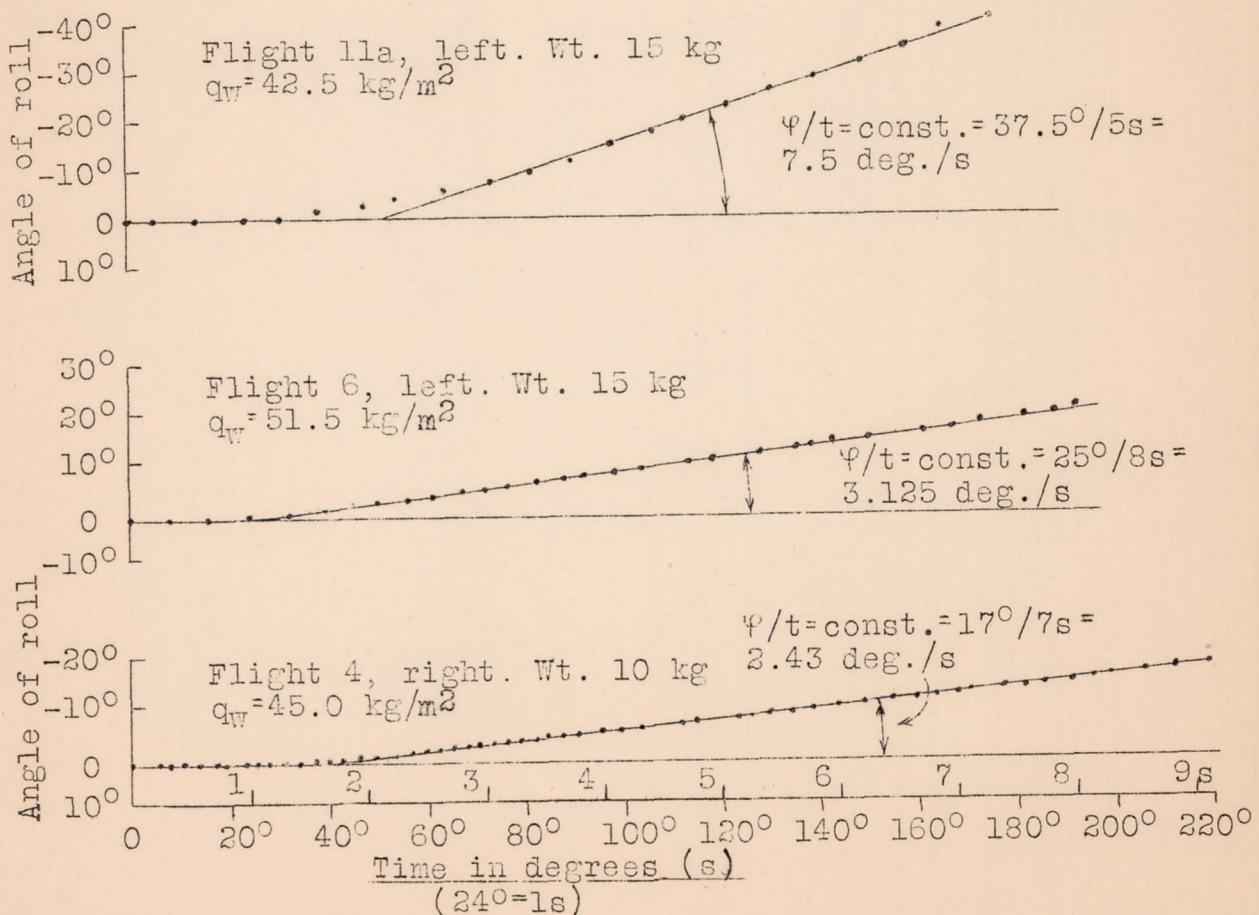


Fig. 36